FACE RECOGNITION AND INTELLIGENT SOFTWARE AGENTS – AN INTEGRATED SYSTEM

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BY

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A Written Prepared Statement for Emerging Technologies in the New Millennium

This written prepared statement for the U.S. Senate Committee on Commerce, Science and Transportation elaborates on the testimony presented by Dr. Helena S. Wisniewski, Vice President, Information Technology, ANSER, to the Subcommittee on Science, Technology and Space on May 12, 1999, regarding Emerging Technologies in the New Millennium.

Introduction
This statement is divided into two main sections:

I. The First Section is an Overview, which elaborates on the verbal testimony presented on May 12, 1999 before the subcommittee. The Overview focuses on three main points:
- How ANSER is satisfying critical needs in society.
- The relationships among ANSER, the West Virginia Law Enforcement Community and the West Virginia Technology Community
- The impact of federal funding on this and related research, and what the future holds.

II. The Second Section describes ANSER s Integrated System for identifying missing children beginning with a description of its components
- Intelligent Software Agent (ISA) Technologies and
- Real Time Face Recognition

Section I - The Overview

1. How ANSER is Satisfying Critical Needs in Society

ANSER is helping to satisfy critical needs in society today by:
Helping to fight cyber crime.
Preventing unauthorized access to databases, networks and facilities.

The Internet has become an important part of everyday life and will have even a greater impact in the new millennium. Its rapid growth and pervasiveness has provided benefits, but also provides a vehicle for crime. Cyber-crime is a growing concern and is very labor intensive to combat

In a networked world our expectation for access from anywhere is high, so is our vulnerability to unauthorized access. Creating an integrated system to locate individuals quickly and reliably in networked responds to these needs.

ANSER is providing solutions to satisfy these needs through the development and integration of its advanced technologies – Intelligent Software Agents (ISA) and Real Time Face Recognition.

ANSER s objective is to provide the law enforcement community with automated digital tools to increase efficiency in locating and identifying violators and victims. The overriding goal is to keep law enforcement ahead of criminals.

These tools can also be used to provide positive individual identification, reducing the vulnerability of unauthorized access to databases, networks and facilities.

The ISAs continuously and autonomously search and retrieve relevant information and images from the thirteen million web sites on the Internet. They operate twenty four hours a day, seven days a week. They act as your personal assistants and gather and filter the information to meet your needs.

Face recognition is part of the field of biometrics, which is one of the fastest growing technology fields today. The face recognition technology can compare 10,000 images a second to a single image using a commercially available 450 MHz PC. It is scalable - its speed increased an order of magnitude within a year. This was possible through improvements in the algorithms. The new Pentium 800 MHz PCs alone can double the speed, and coupled with improvements in the algorithms the next century will witness even greater improvements. It is a technology that is here today and getting better.

The integration of these advanced technologies into an easily used system distinguishes the ANSER solution. The integrated system decreases labor intensive tasks and automates the processes required to solve critical society needs – for example, it expedites the recovery of missing and exploited children and their exploiters.

ANSER has developed and is using prototype versions of its integrated system with law enforcement agencies for the following pilot programs:
The West Virginia State Police - to locate missing and exploited children
US Customs - to help eradicate child on line pornography;
The South Florida High Intensity Drug Trafficking Area (HIDTA) - for real time video surveillance.
An additional pilot with the FBI is being formulated. These pilots will further evaluate and validate the technology and assess its utility in real world environments.

2. The Relationships Among ANSER, the West Virginia Law Enforcement Community and the West Virginia Technology Community

The majority of the work is performed in ANSER s West Virginia office. West Virginia has become a center for Law enforcement research and development. The following are some examples. At the West Virginia University a department of forensic identification

has been started. The National Center for Identification Technology, which began as part of the West Virginia High Technology Consortium is at West Virginia University as part of the Computer Sciences and Electrical Engineering Department in the College of Engineering and Mineral Resources. The National White Collar Crime Center is also located in Fairmont and Morgantown. The West Virginia State Police have taken the lead to fight cyber-crime, and host one of our pilot programs to find missing and exploited children. ANSER has joined this community and formed research and development relationships with West Virginia University and local software companies.

3. The Impact of Federal Funding in This and Related Research, and What the Future Holds

Government research funding is providing significant benefits to society. The face recognition tools that ANSER is further developing had their origins in Department of Defense (DOD) mathematical sponsored research and are becoming a reality due to Department of Justice (DOJ) funding.

The Face Recognition technology began with DARPA s Applied and Computational Mathematics Program (ACMP) in the mid 1980 s as a solution to a fluid dynamics problem. The ACMP was created and managed by Dr. Wisniewski. The researchers[1] were searching for an interesting surface to describe the fluid flow over, and the face is an interesting surface. This was the start of the Eigenface Method for face recognition, which is among the most widely used face recognition techniques used today.

Subsequent to DARPA support, a commercial company called Visionics was created and continued to further develop face recognition technology using the DARPA developed Eigenface Method. DARPA is continuing work in biometrics in the areas of speaker and voice recognition, but still maintains an interest in face recognition.

Through a new initiative, DOJ funding is bringing these tools into reality. This illustrates an excellent example of dual use technologies across government agencies.

The development of Intelligent Software Agents and their integration with Face Recognition Technology into a system is being accomplished by ANSER through two recent grants from the National Institute of Justice. This new initiative started in August 1997, and is the DOJ funding referenced earlier. As part of this initiative, ANSER is developing the ISAs, and has partnered with companies such as Visionics to enhance and further develop face recognition technology.

Included as part of this funding is the charter to create the pilot projects with state and federal law enforcement agencies. This will provide benefit to law enforcement and meet critical society needs

[1] Please refer to references listed at the end of this manuscript.

ANSER is advancing the state of the art in these technologies and focuses on their research and development. ANSER plans to work with vendors to bring the technology to market.

Due to the initial technical risk involved in the research, development and fielding of these technologies and their integrated systems it is unlikely that the private sector would underwrite such an effort.

The future opens the door to many additional applications that will transform the way we communicate and do business. These applications include – computer security, banking security and portal access. However, the intermediate step needs to be completed first – validation of the integrated system and enhancements to the individual technologies to ensure client expectations are met.

ANSER s role, as a Non For Profit is focused on the research and development through to prototype, and evaluation through pilot programs, and ANSER will work with companies to commercialize.

Intelligent agent research will lead to evolutionary societies of agents, using the computing power of the web itself. Agents will cooperate to work more quickly and will bring more customized results faster to meet user needs.

Real time video recognition of the face in the crowd will be an important enhancement for face recognition. The need for integration of different biometrics to ensure correct identification will grow with the Internet and with remote access needs. The nineties watched biometrics enter the IT mainstream, and predictions indicate a biometrics explosion in the next century for individual identification and security.

The continued growth in size and capability of the Internet will demand the need for a scalable information infrastructure, which will be critical for building and using large, highly-reliable and secure systems driven by this growth. The ISAs and real time face recognition technologies can be useful elements to help develop such an information infrastructure. During the first five to ten years of the net century, these technologies and systems should be available to the average consumer.

The willingness of the Federal Government to sponsor research and development has benefited and will continue to benefit society. ANSER s integrated system has already been successful.

Section II - System and Technology Description

1. Intelligent Software Agents

An agent is a person who acts on behalf of another person, and has that person s authority to do so. An Intelligent Software Agent (ISA) is a software program that acts as an agent. ISAs can also be thought of as robotic personal assistants since they can process information autonomously and continuously - 24 hours a day, seven days a week with precision. They are categorized by their degree of functionality and intelligence. Methods to provide intelligence include neural networks, genetic algorithms, reinforced learning, and text categorization.

ANSER has developed several unique ISAs that are incorporated into alpha versions of products for locating missing and exploited children and their exploiters. These products are being used in the pilot programs described in Section I. Examples of ANSER s ISAs include the following:

Bloodhound traverses the World Wide Web (WWW) and sends back information about text and image files.

Newshound traverses Internet newsgroups and sends back information about text and image files.

URL Monitor browses specific Internet sites looking for changes.

Face Recognition Engine analyzes each image file to locate heads and faces and matches each face to a set of stored face images.

Future development includes evolutionary societies of agents that will use the computing power of the web itself. These agents will cooperate to work more quickly and will bring more customized and tailored results faster to meet user needs.

2. Face Recognition

Real time face recognition is part of the field of Biometrics. Biometrics is the ability for a computer to recognize a human through a unique physical trait. Face recognition provides the capability for the computer to recognize a human by facial characteristics. During the 1990s, biometrics entered the mainstream of Information Technology. Today, biometrics is one of the fastest growing fields in advanced technology. Predictions indicate a biometrics explosion in the next century, to authenticate identities and avoid unauthorized access to networks, databases and facilities.

The following discussion outlines a procedure for face recognition, and states the very basic elements of the Eigenface Method. The algorithm that is implemented in the system had its beginnings using Eigenface Methods and it has enhanced and incorporated further work. For a mathematically precise and detailed account of the Eigenface Method, the reader is referred to the papers in the list of references.

The first step in face recognition is to define the facial features so that a computer can understand it. A computer facial image is a set of picture elements (pixels) of varying colors and shadings.

Consider the following simplification to describe a black and white image of a face in terms of position and gray level at each location.
Cover the facial image with a square graphical grid.
The nodes of the graph provide a means of indexing the location of the pixels and provides a way to describe the face in terms of position and gray level of the image at each location.
Suppose that the black and white image is a square array of pixels of 100 x 100 = 10,000 pixels.
Assume there are 256 gray levels for each pixel.
Each pixel (gray scale value) is a byte (8 bits).
To measure the difference in intensity or reflectivity takes
8 x 10,000 = 80,000 bits.

Labeling the graph provides a vector of information unique to the given face. Repeating this process with a large number of faces creates an ensemble of vectors that together capture a representative sample of human facial features. However, this graphical process necessitates storage of a large number of entries (10,000) of information to represent and compare faces.

The means to represent faces with fewer entries to reduce storage and processing requirements is the Eigenface Method. The German word eigen means own or individual and the method gets its name from the fact that it preserves the features that are unique to an individual face. This involves a series of steps that will reduce the complexity of the calculations used to compare images. It results first in a small number, say 50, of facial images, the eigenfaces of the method, which become the basis for representing all faces. Each picture will become a linear combination of all the eigenfaces. An image s representation consists of essentially one eigenvalue per eigenface in the database. This procedure decreases processing because the calculations are now performed with 50 entries versus the 10,000 we started with. So if we have an image and want to compare it against a database of images, all preprocessed using this method, we will compare only 50 entries against 50 entries, versus 10,000 against 10,000. The number of points in our example is reduced from 10,000 (or 80,000 bits) to only 50 (or 400 bits). An average of compression of 200 to one or greater is obtained using this method with 50 eigenfaces.

Figure 1 illustrates an Eigenface Method that has calculated eight eigenfaces. These eight eigenfaces may be linearly combined to reconstruct any face in the database. As the number of eigenfaces is increased from 8 to 20, 50 or 100, there will be improved definition of each pixel by pixel image. For example, Figure 2 is a 100 x 100-pixel image (10,000-pixel array). Figure 3 illustrates an improved representation as 20, 50, and 100 eigenfaces are combined. In this case, with 50 eigenfaces the face is recognizable and

provides a fairly good match to the original 100 x 100-pixel array. Here there is approximately 200:1 compression in going from the pixel by pixel to the eigenface representation.

Image databases are preprocessed by this method. New facial images can be against the database. Matching is based on using the smallest mean squared error to images in the database.

There are significant benefits in applying the Eigenface Method instead of the pixel by pixel method. There is a significant reduction in the size of the database as compressions of 200:1 or greater ensue. There is also a great reduction in processing time as calculations are performed with 50 points vs. thousands with the pixel by pixel method.

3. The Integrated System – An Example

ANSER s discriminator is the integration of the intelligent software agents and face recognition technology into systems. An example of one of ANSER s systems is the Missing Children Locator Agent (MCLA), which can be used to expedite the search and locating of missing children and the persons who abduct them. This is currently being used in the West Virginia State Police pilot program.

Photographs are extremely important in cases involving missing children. With the rapid growth and pervasiveness of the Internet in our daily lives vast amounts of open source data are available that may be relevant to missing children cases. For example, children and parents are creating home pages, and schools are publishing yearbook pictures on the Internet. Currently, it is a very labor intensive, time consuming task to search the web sites on the internet, as well as matching a single photo against a large database of images. Law enforcement officers do not have the tools to expedite the process of continuously searching the 13 million web sites of the Internet and locating and retrieving relevant photographs and information, and, then comparing them to large databases of missing and exploited children.

The Solution is ANSER s Missing Children Locator Agent (MCLA). ANSER has developed this as an integrated system comprised of Intelligent Software Agents (ISAs) and face recognition engines. MCLA continuously and autonomously searches the Internet – twenty four hours a day, seven days a week – for images and information about missing or exploited children. When an image is found, MCLA first determines if it is an image of a person. If so, the system compares the image to the database of missing and exploited children, provided by the West Virginia State Police. The system maintains for each missing child a list of the best matches, and updates this list as its search continues. Additionally, the system stores pertinent data about the site where each matching image was found – such as the URL, the site Internet address and the registered owner of the site. This site data can help the case manager uncover additional information about the person in the matching image as the investigation proceeds.

The investigator periodically reviews the list of best matches for a particular missing child. The results can be accessed either over the Internet or an Intranet through a dynamically generated web-based user interface. As an additional feature, a user can provide an input image as a query. The query will be compared with a gallery of missing children and the user can inspect the closest matches between the query image and the missing children in the gallery.

The Missing Children Locator Agent provides the following benefits:
Decreasing the need for time consuming labor intensive tasks.
Searching the Internet – faster and more accurately than a human.
Providing pertinent data about web sites that have matching images – saving valuable law enforcement time and resources.

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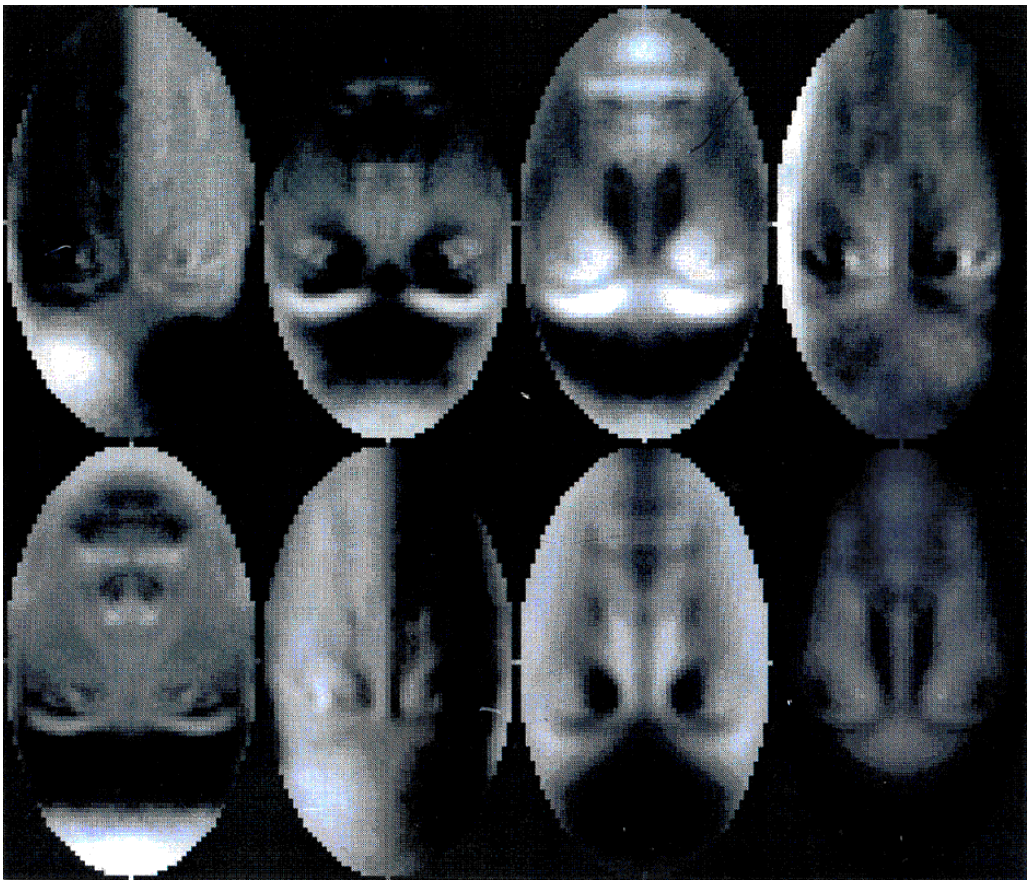

Figure 1
IDEAL STATE SPACE EIGENFACES

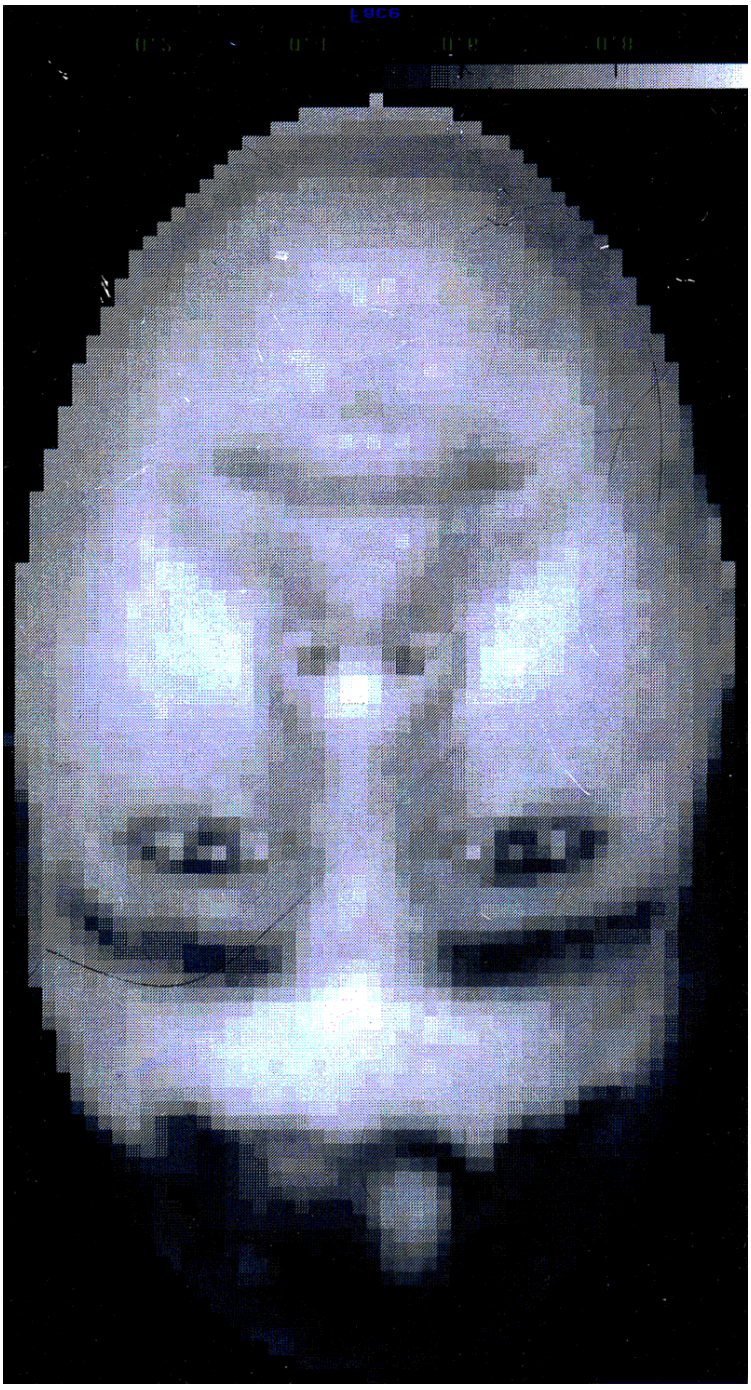

Figure 2
STATE SPACE 102 X 10^2 GRAY LEVELS